

THE EFFECTS OF EXTINCTION ON HUMAN PERFORMANCE FOLLOWING
EXPOSURE TO FIXED RATIO SCHEDULES OF REINFORCEMENT

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This experiment examined the effects of extinction on rate of responding and several topographical and temporal measures in adult humans. Three college students were trained to type the sequence 1•5•3 on a numeric keypad on a computer. The subjects were exposed to different fixed-ratio schedules of reinforcement (FR1, FR 5, and FR10 respectively) and extinction. Subjects displayed typical schedule performances during the maintenance phase of the experiment. During extinction the performances were disrupted, they showed a “break and run” pattern and a general decrease in responding. Also, new topographical and temporal patterns emerged. These data are consistent with those reported for non-human species and special human populations.

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CHAPTER 1

INTRODUCTION

Schedules of reinforcement have wide applicability for use in establishing baseline measures in behavior analysis (e.g., Sidman, 1960; Zeiler, 1984; Baron, Perone, & Galizio, 1991). This is in part due to the generality of performances generated across species as diverse as rats (e.g., Skinner, 1938; Keller & Schoenfeld, 1950), pigeons (Ferster & Skinner, 1957), goldfish (Wertheim & Singer, 1964), and monkeys (Verhave, 1959).

Humans, however, have been rather enigmatic in regard to performance under schedules of reinforcement. It has been very difficult to produce characteristic schedule performances with human subjects. For example, Weiner (1964) and Weiner (1969) were unable to show characteristic fixed ratio and fixed interval schedule performances with normal adults. Bentall, Lowe, and Beasty (1985) were unable to produce characteristic performances with children older than 2-years. This has led the field to believe that schedule effects in operant labs can be seen only in non-verbal subjects. Apparently, adults' verbal behavior interferes with schedule performance. However, this issue is far from settled. Other experimenters point to differences in methodology that may also account for the disparity of effects (e.g., Shull & Lawrence, 1998; Baron, Perone, & Galizio, 1991).

Furthermore, when characteristic schedule performances have been obtained with human subjects, these performances have been insensitive to changing contingencies.

That is, changing schedules or applying an extinction procedure has had little or no effect on the subjects' behavior. For example, Shimoff, Catania, and Mathews (1981) produced high rates of behavior using random ratio schedules and then changed the contingency to a DRL (differential reinforcement of low rates) schedule that arranges for the delivery of consequences only for long interresponse times. However, they found that high rates of behavior maintained during the DRL condition. Hayes, Brownstein, Zettle, Rosenfarb, and Korn (1986a) used instructions to produce high and low rates of behavior and then exposed the subjects to fixed ratio and DRL schedules. They found that performances were more closely aligned to the instructions than the programmed contingency. Hayes, Brownstein, Haas, and Greenway (1986b) replicated Hayes et. al. (1986a), but used extinction in addition to changing schedule contingencies and found that very few subjects showed behavior change when exposed to an extinction procedure. Shimoff, Catania, and Mathews (1981) consider insensitivity to changing contingencies to be "the defining property of instructional control." (p. 207)

The term "sensitivity" has been used extensively in the literature on schedule control and rule governed behavior. Madden, Chase, and Joyce (1998) caution us that the term "sensitivity" has been a confusing, variously defined concept in behavioral research. They found two common uses of the term "sensitivity." The first use of the term refers to the comparison of behavior across species or organisms. Behavior is said to be "insensitive" to schedule control when performances characteristic of a specific schedule of reinforcement are not obtained when the subject is exposed to that schedule contingency (e.g., Bentall, Lowe & Beasty, 1985; Bentall & Lowe, 1987). The second use of the term refers to the comparison of behavior across changing conditions for a

single organism (e.g., Hayes, Brownstein, Haas & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Shimoff, Catania, & Mathews, 1981). Part of the confusion over the term, “sensitivity,” stems from the fact that researchers point to instructions and self-instructions occurring during the experiment to account for insensitivity to schedule contingencies whether they are talking about across-species behavior comparison (e.g., Weiner, 1964; Weiner, 1969; Weiner, 1970; Bentall, Lowe & Beasty, 1985; Bentall & Lowe, 1987) or within-subject comparison of behavior across changing conditions (e.g., Hayes, Brownstein, Haas & Greenway, 1986; Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986; Shimoff, Catania, & Mathews, 1981).

In spite of the confusion about the uses of sensitivity, there is agreement that seeing changes in behavior correlated with changes in programmed contingencies is necessary for determining whether human performances are under the control of schedule contingencies or under the control rules or instructions. For example, Hayes and Ju (1998) recommend the use of unannounced changes in schedule contingencies or the deployment of an extinction procedure as a tactic for ensuring that human schedule performance is under the control of programmed contingencies rather than rules or instructions. If the performance changes with the contingency, then we can be confident that the performance is sensitive to schedule control. In the present study, behavior will be considered sensitive to changing contingencies when changes in the subject’s behavior are correlated to changes in programmed contingencies. Also, “generality of results” (see Sidman, 1960) will be used when examining the results of this study in the context of other studies with other species.

There have been some exceptions showing that human subjects are sensitive to changes in schedule contingencies. For example, Flyger and Rosales-Ruiz (1997) and Rosales-Ruiz, Anderson, Hensley, and Koremura (1999) demonstrated sensitivity to changing fixed ratio and fixed interval schedule contingencies with adult humans. Additionally, the performances generated in these studies showed similar performances to those generated by non-human subjects in the experimental literature. Their success may be due to the fact that they attempted to create an analog environment to the operant chamber used in non-human research that would include features not seen in previous human operant research. The response was shaped rather than instructed and the chain of events typically found in an operant chamber was replicated. Furthermore, sound clips from television and cartoons were used as reinforcers that could be consumed immediately rather than points or tokens, which are typically accumulated and used at a later time. This experiment uses the apparatus developed by Flyger and Rosales-Ruiz (1997).

There have also been a few cases in the study of schedules of reinforcement where humans have been shown to be sensitive to extinction procedures (e.g., Hutchinson & Azrin, 1961; Weissberg & Fink, 1966). The subjects in these studies, however, might not be representative of normal adults due to a lack of verbal development. Also, in the applied literature, extinction has been shown to be an effective technique to reduce responding (see Lerman, Iwata, & Wallace, 1999). If performance under extinction is to be used as a test for schedule control, as Hayes & Ju (1998) suggest, then we should see changes in rate of response, changes in temporal measures, and changes in topography similar to the ones found with non-humans.

One well-documented effect of extinction is the deceleration of rate over time (e.g., Skinner, 1938; Ferster and Skinner, 1957; Keller & Schoenfeld, 1950; Weissberg & Fink, 1966; Hutchinson & Azrin, 1961). This effect has been shown to be a function of the ratio value of the fixed ratio schedule. Behavior exposed to higher fixed ratio schedule values decelerates at a lower rate than behavior exposed to lower schedule values. In other words, higher fixed ratio schedule values are more resistant to extinction (e.g., Skinner, 1938; Keller & Schoenfeld, 1950).

If extinction effects are examined on a moment-to-moment basis, cumulative records reveal a “break and run” pattern of responding during extinction in which periods of high rate responding (“bursts” or “runs”) are intermixed with periods of no responding (“breaks”). This effect has been demonstrated with pigeons (Ferster & Skinner, 1957), rats (e.g., Skinner, 1938; Keller & Schoenfeld, 1950), human children (Weissberg & Fink, 1966), and adult humans diagnosed with schizophrenia (Hutchinson & Azrin, 1961).

The effects can also be seen on the distribution of interresponse times (IRT) and response durations during extinction. Blough (1963) found that pigeons displayed a bimodal distribution of IRTs during fixed ratio schedules of reinforcement. During extinction, the pigeons showed a transition from the bimodal IRT pattern seen with the fixed ratio schedules to a variable, single modal pattern of responses. Millenson and Hurwitz (1961) studied the distribution of IRTs in rats after exposure to a continuous schedule of reinforcement and found patterns similar to Blough (1963). Another temporal measure affected by extinction is response duration. Margules (1961) studied response duration in rats during extinction after exposure to a continuous schedule of

reinforcement (FR-1) and found that response durations at the operant level were variable, the response durations were tightly distributed during FR-1, and were variable during extinction.

In addition to the effects on rate of responding and other temporal measures, changes in topography as a result of extinction have been reported in the literature. Eckerman and Lanson (1969) studied the effects of extinction on the location of keypecks around a response key by pigeons after exposure to continuous schedules of reinforcement. The pigeons produced very little variability when keypecks were being reinforced. During extinction, the pigeons showed a great deal of deviation in keypeck location. These data is consistent with the results achieved by Antonitis (1951) with rats.

Another common effect of extinction is the emergence of new behaviors. One example of the emergence of new behaviors was provided by Azrin, Hutchinson & Hake (1966). They trained pigeons (the experimental pigeons) under a continuous schedule of reinforcement to peck a key for food with another bird (the target pigeon) present in the chamber. While the reinforcement contingency was in place the experimental pigeons only pecked the key and ate food. When exposed to extinction, the experimental pigeons vigorously attacked the target pigeon in addition to pecking the key.

This experiment analyzes the effects of extinction on human behavior maintained by a fixed ratio schedule of reinforcement. As can be seen, extinction affects the behavior of non-humans in ways other than simply reducing behavior. Will the behavior of adult humans be sensitive to an extinction procedure and can we expect to see similar results as those seen in the literature with non-verbal subjects?

CHAPTER 2

METHOD

Subjects and Setting

One male and two female college students participated in this study. They received \$5.00 for each session they attended. The money was not contingent on the subject's performance. Sessions were conducted in the Department of Behavior Analysis at the University of North Texas. Each session lasted 20 minutes.

Apparatus

The apparatus consisted of a Pentium (TM) computer, monitor, mouse, a keyboard, and a set of audio headphones. Subjects sat in front of the monitor and had access to the computer keyboard and mouse and wore the headphones. Through instructions, the subject's responses were restricted to the keys 1-9 on the numeric keypad. The response topography targeted for this experiment was pressing the keys 1, 5, and 3 in that order (see Figure 1). Each occurrence of the 1•5•3 response sequence produced a click sound. At the beginning of the session, a button with the word "START" on it was presented on the screen (see Figure 2). A mouse-click on this button produced a 3 x 3 grid of gray squares in the center of the screen. The 3 x 3 grid was a square of approximately 8 cm with each of the individual squares being 2 cm. A border enclosed the grid. Each square looked like a three-dimensional button, and was separated from the others by .5 cm. When the experiment began, the squares always appeared "popped out" and changed their appearance depending upon key-presses made by the

subject. Below the grid was a 5.5 cm square (see Figure 3). Under certain experimental conditions, a button with a speaker icon would appear in this square accompanied by a chiming sound (see Figure 4). When the subject pressed this button with the mouse, a random sound clip from a bank of 214 sounds was played. The sounds had playing lengths from .38 s to 6.639 s. The sounds were used as response consequences and consisted of humorous quotes, cartoon-character sounds, or interesting special effects. At the end of the session, a dialog box appeared to the subject with the words “Thank You.”

Experimental Procedures

The experiment consisted of three phases. The first phase was response acquisition. The second phase of the experiment was fixed ratio schedule maintenance. The final phase was extinction.

Response acquisition. After the subject was seated in front of the computer, the experimenter said to the subject, “Press any of these nine keys,” while concurrently pointing at the nine keys of the numerical keypad. Then the experimenter pointed to the area on the screen below the 3 x 3 grid and said, “A button will occasionally appear here. When it does, click it with the mouse.” At this point, the experimenter left the room.

All squares in the grid on the computer screen initially had a “popped-out” appearance. Pressing any key in the middle column of the keypad (2, 5, or 8) or the right column of the keypad (3, 6, or 9) produced no change in the grid, however, when the subject pressed any key in the left column of the numeric keypad (1, 4, or 7), the corresponding square on the grid changed to a “pressed-in” appearance. At this point, any key the subject pressed in the middle column caused the corresponding grid square to change to the “pressed-in” appearance. Any key pressed in the left or right columns of

the numeric keypad would not produce a change in the grid. After the subject presses a key in the middle column, only a key pressed in the right column produced a change in the grid. A key press on the left column of the keypad reset the grid and caused the corresponding square in the left column of the grid to appear “pressed-in.” Figure 5 shows a sample sequence.

If the subject pressed a sequence of keys that resulted in the 1, the 5, and the 3 (1•5•3) grid squares to appear “pressed-in,” two events immediately happened. First, a chime sound was played. Second, a button appeared below the 3 x 3 grid. When the subject clicked this button, a random sound clip was played from the bank of 214 sounds. Only the 1•5•3 sequence produced the button and sound clip. Figure 6 shows a response sequence meeting the response requirement and the consequences that follow the response.

Schedule maintenance. Three schedules of reinforcement, FR-1, FR-5, and FR-10 were used during schedule maintenance. The apparatus operated in the same fashion during the schedule maintenance phase of the experiment except that consequences were programmed to occur after 1, 5, or 10 target responses. Target responses not scheduled for reinforcement produced a click sound. AA-Sp98 was exposed to an FR-1 schedule of reinforcement and to extinction. TW-Su98 was exposed to FR-1 during acquisition, FR-5 during the schedule maintenance phase of the experiment and extinction. GS-Sp98 was exposed to FR-1 during acquisition, FR-10 during schedule maintenance, and extinction.

Extinction. During the extinction phase, no scheduled consequences were delivered. The grid still changed in accordance to the subject’s key presses and the target response always produced the click.

Dependent Variables

The effects of extinction on behavior following schedules of reinforcement was measured on frequency of responding, changes in frequency of responding (celeration), response duration, interresponse time (IRT), interkeystroke time (IKT), response length in keystrokes, emitted over time, and the frequency of response patterns.

Celeration. Celeration measures the amount of weekly change in the frequency of behavior expressed as a factor which gives direction and slope. A multiplication sign (\times) is used if there is an upward trend in the data and a division sign (\div) is used if there is a downward trend. Celerations were calculated by drawing a line that best fit the trend of the data during the schedule maintenance and extinction phases of the experiment on a Standard Behavior Chart (Oliva, 1981).

Frequency of responding. Cumulative records were used to analyze within session moment to moment changes in frequency of responding. Frequency jumps were calculated using the Standard Behavior Chart. A frequency jump is the vertical distance between the celeration during schedule maintenance and the frequency of the first session of extinction. The frequency jump is calculated by dividing the highest frequency by the lowest. Frequency jumps are expressed as a factor which gives the direction and the magnitude of the jump. A multiplication sign (\times) is used if the jump is to a higher frequency and division sign (\div) is used if the jump is to a lower frequency (Lindsley & Rosales-Ruiz, 1992).

Response Duration. Response duration was the amount of time measured from the first keystroke of a new pattern to the last keystroke of that pattern.

Interresponse time. Interresponse time was the amount of time measured from the last keystroke of a completed pattern to the next keystroke.

Interkeystroke time. Interkeystroke time was the amount of time between individual keystrokes.

Keystrokes. Keystrokes were specified by their label on the keyboard.

Pattern. A pattern contained three parts. The first part of the pattern could consist of any number of keystrokes on the middle or right columns of the numeric keypad followed by a terminal keystroke on any of the keys in the left column. The second part of the pattern consisted of any number of keystrokes in the left or right columns followed by a terminal keystroke in the middle column. The third part could consist of any number of keystrokes in the left of middle columns followed by a terminal keystroke in the right column. This can be expressed as a regular expression with the pattern of `/[^147]*([147])[^258]*([258])[^369]*([369])/` (see Friedl, 1996 for a detailed explanation of regular expressions).

Pattern length. The pattern length is the number of keystrokes that make up a pattern.

CHAPTER 3

RESULTS

Figure 7 shows the rate of the target response ($1 \bullet 5 \bullet 3$) for subjects AA-Sp98, TW-Su98, and GS-Sp98 during acquisition, schedule maintenance, and extinction. AA-Sp98 (left graph) acquired the target response during the first session. Her rate of responding increased from 0.35 responses per minute (r/min) to 18.6 r/min in the second session and stabilized to approximately 20 r/min during sessions 3 and 4. During extinction, her rate of responding jumped down ($\div 2.3$) and turned down ($\div 5$).

TW-Su98 (middle graph) acquired the target response during the Session 2 and responded at a rate of 11.6 r/min. During FR-5 schedule maintenance, he responded at rates of 58.45, 66.2, 85.2, and 49.45 with a celeration of $\times 1.0$. His rate of responding jumped down ($\div 3$) and turned down ($\div 2.8$) during extinction.

GS-Sp98 (right graph) acquired the target response during Session 2 and responded at a rate of 11.25 r/min. During FR-10 schedule maintenance, she responded at rates of 48.15, 59.35, and 64.05 r/min with a celeration of $\times 1.4$. Her rate of responding jumped down ($\div 1.8$) and turned down ($\div 1.6$) during extinction.

Figure 8 shows cumulative records of the target response for AA-Sp98 during the last session of FR-1 (top graph) and the first session of extinction (bottom graph). AA-Sp98 responded at a steady rate of approximately 22 r/min with 4 breaks in responding including a 45 s break at 4.75 minutes into the session, a 10 s break at 8 minutes, a 30 s break at 12.5 minutes, and a 20 s break at 17.75 minutes. During the first session of

extinction, AA-Sp98 responded at a rate of approximately 12 r/min for 2 minutes followed by 3 bursts of responding at a rate of between 75 and 100 r/min during the next 2 minutes. At minute 4, AA-Sp98 begins a 12.5 minute break in responding followed by 2 short bursts of responding at rates of 190 r/min and 90 r/min. At minute 16.5, AA-Sp98 stopped responding for approximately 2 minutes. AA-Sp98 ended the session with a 30 s burst of responding at a rate of 100 r/min followed by a 45 second break in responding.

Figure 9 shows cumulative records of the target response for TW-Su98 during the last session of FR-5 (top graph) and the first session of extinction (bottom graph). TW-Su98 responded at a steady rate of approximately 50 r/min with two short breaks occurring at 30 seconds and 9.5 minutes into the session during the last session of FR-5. During the first 15 s of the first session of extinction, he responded at a rate of 50 r/min followed by a brief pause. During the next four minutes, he responded 200 times with 6 bursts of high rate responding and five breaks in responding. During the next 12.5 minutes, his responding consisted of shorter bursts of responding and longer pauses with an overall rate of 22 r/min. At minute 16, he responded at a high rate for approximately 45 seconds and ends the session with a period of responding at approximately 15 r/min.

Figure 10 shows cumulative records of the target response for GS-Sp98 during the last session of FR-10 schedule maintenance and the first session of extinction. GS-Sp98 responds at a steady rate of approximately 64 r/min during the last session of schedule maintenance with a 30 s break in responding occurring at 8.5 minutes. She responded 200 times during the first 7 minutes of the first session of extinction with 6 response bursts and breaks of 15 s, 30 s, 1 min, 30 s, 1 min, and 1 min. She responded 500 times over the course of the next 10 minutes with a 15 s break occurring at 9.5 minutes into the

session. This was followed by a three-minute break in responding and 1 minute of sustained responding at approximately 100 r/min.

Figure 11 shows scatterplots of response durations of all left to right responses as they occur in time during the last FR session and the first session of extinction for subjects AA-Sp98 (top graph), TW-Su98 (middle graph), and GS-Sp98 (bottom graph). AA-Sp98 displayed a bimodal pattern of response durations during the last session of FR-1 with a mean of 0.36 s and a standard deviation of 0.21 s. The primary mode (lower distribution) was 0.2 s and the secondary mode was 0.5 s. During the first session of extinction, she displayed a highly variable, single modal distribution of response durations with a standard deviation of 1.35 s and a mean of 0.65 s.

TW-Su98 displayed a single modal pattern of response durations during the last session of schedule maintenance with a standard deviation of 0.51 s and a mean of 0.59 s. The pattern consisted of either concentrated durations of approximately 0.5 s or dispersed durations between 0.1 s and 2.5 s. During the first session of extinction, TW-Su98 displayed a single modal distribution of response durations with a standard deviation of 1.44 s and a mean of 90.09 s. Variability increased as the session progressed.

GS-Sp98 displayed a bimodal distribution of response patterns during the last session of FR-10 with a standard deviation of 0.48 s and a mean of 0.51 s. The primary mode was 0.3 s, and the secondary mode was 4 s. During the first session of extinction, she displayed a variable, bimodal distribution of response durations with a standard deviation of 2.48 s and a mean of 0.72 s. The primary mode was 0.4 s, and the secondary mode was 3 s.

Figure 12 shows interresponse times (IRT) of all left to right responses as they occur in time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98, TW-Su98, and GS-Sp98. AA-Sp98 displayed a single modal distribution of IRTs during the last session of FR-1 with a standard deviation of 2.4 s and a mean of 2.22 s. During the first session of extinction, she displayed a highly variable, single modal distribution of IRTs with a standard deviation of 30.46 s and a mean of 0.41 s.

TW-Su98 displayed a highly variable, bimodal distribution of IRTs with a standard deviation of 0.62 s and a mean of 0.58 s. The primary mode (lower distribution) was 0.3 s and the secondary mode (upper distribution) was 2 s. He displayed a single modal distribution of IRTs during the first session of extinction with a standard deviation of 2.07 s and a mean of 0.73 s.

GS-Sp98 displayed a bimodal distribution of IRTs with a standard deviation of 1.02 s during the last session of FR-10. The primary mode (lower distribution) was 0.25 s and the secondary mode (upper distribution) was 3 s. During the first session of extinction, she displayed a highly variable, single modal distribution of IRTs. The standard deviation of the IRT distribution during the first session of extinction for GS-Sp98 was 2.12 s, and the mean was 0.59 s.

Figure 13 shows the time between individual keystrokes (IKT) as they occur in time for subjects AA-Sp98, TW-Su98, and GS-Sp98 for the last session of schedule maintenance and the first session of extinction. AA-Sp98 displayed a variable, bimodal distribution of IKTs during the last session of FR-1 with a standard deviation of 1.68 s and a mean of 0.3 s. The primary mode (lower distribution) was 0.2 s and the secondary

mode (upper distribution) was 2.25 s. During the first session of extinction, she displayed a highly variable, single modal distribution of IKTs with a standard deviation of 16.66 s and a mean of 4.15 s.

During the last session of schedule maintenance, TW-Su98 displayed a bimodal distribution of IKTs with a standard deviation 0.41 s and a mean of 0.3 s. The primary mode (lower distribution) was 0.2 s and the secondary mode was 1.85 s. During the first session of extinction, he displayed a variable, single modal distribution of IKTs with a standard deviation of 0.91 s and a mean of 0.24 s.

GS-Sp98 displayed a bimodal distribution of IKTs with a standard deviation of 0.63 s and a mean of 0.29 s in the last session of FR-10 schedule maintenance. The primary mode (lower distribution) was 0.25 s and the secondary mode (upper distribution) was 2.5 s. During the first session of extinction, she displayed a single modal distribution of IKTs with a standard deviation of 1.69 s and a mean of 0.37 s.

Figure 14 shows keystrokes as they occur in time for subjects AA-Sp98 (top graph), TW-Su98 (middle graph), and GS-Sp98 (bottom graph). All subjects show very little variability in keystroke distribution during the last session of schedule maintenance with most responding consisting of 1, 3, and 5. TW-Su98 and GS-Sp98 showed a short period of variability during the early part of the session. Additionally, TW-Su98 showed a short period of variability at approximately 10 minutes into the session. During extinction, AA-Sp98 showed variable responding on all keys (1-9) for the first 4 minutes of the first session of extinction. All remaining keystrokes are either 1, 3, or 5. TW-Su98 displayed variable responding on all keys throughout the first session of extinction with concentrations on keys 1, 3, and 5 from minute 12.5 until minute 19. He responded

almost exclusively on keys 1, 3, and 5 in the last minute of the session. GS-Sp98 responds exclusively on keys 1, 3, and 5 during the first 30 s of the first session of extinction. She then responds on all keys until minute 7 with breaks in responding at minute 2 and again at minute 4. From minutes 7 to 16, GS-Sp98 shows very little variability in response and a high density of keys 1, 3, and 5. Responding on all keys resumed afterwards and continued for the last 4 minutes.

Figure 15 shows the length of all left to right patterns in keystrokes as they occur in time for subjects AA-Sp98, TW-Su98, and GS-Sp98 during the last session of schedule maintenance and the first session of extinction. During the last session of FR-1, AA-Sp98 displayed a distribution of pattern lengths with a standard deviation of 0.22 keystrokes and a mean of 3.03 keystrokes per response. She displayed a variable distribution of pattern lengths during the first session of extinction with a standard deviation of 2.16 keystrokes and a mean of 3.91 keystrokes per response.

TW-Su98 shows a variable distribution of pattern lengths with a standard deviation of 2.12 keystrokes and a mean of 3.98 keystrokes per response in the last session of FR-5. During the first session of extinction, he displayed a distribution of pattern lengths with a standard deviation of 14.7 keystrokes and a mean of 24.46 keystrokes per response.

GS-Sp98 displayed a distribution of pattern lengths with a standard deviation of 0.63 keystrokes and a mean of 3.13 responses per keystroke during the last session of FR-10. During extinction, she displayed a distribution of pattern lengths with a standard deviation of 1.95 keystrokes and a mean of 3.58 keystrokes per response.

Figure 16 is a frequency distribution of three-key response patterns emitted more than once for AA-Sp98 during the acquisition session (top graph), the last session of FR-1 schedule maintenance (middle graph), and the first session of extinction (bottom graph). AA-Sp98 emitted 27 different three-key response patterns during acquisition. The most frequent patterns were 1•5•3, 1•2•3, 4•5•6, 4•8•9 and 7•8•9. During the last session of FR-1, she emitted responses in the 1•5•3 response pattern almost exclusively. During the first session of extinction, she emitted 12 different three-key response patterns with 1•5•3, 1•2•3, 4•5•6, and 7•8•9 being the most frequent.

Figure 17 is a frequency distribution of three-key response patterns emitted more than once for TW-Su98 during the acquisition session (top graph), the last session of FR-5 schedule maintenance (middle graph), and the first session of extinction (bottom graph). TW-Su98 emitted 23 different three-key response patterns during the acquisition session with 1•5•3 being the most frequent with 223 instances and all other response patterns falling in the range of 2 to 8 instances. During the last session of FR-5, he emitted nine different three-key response patterns. 1•5•3 was the most frequent response pattern with 990 instances. All other response patterns occurred four or fewer times. TW-Su98 emitted 15 different three-key response patterns in the first session of extinction. 1•5•3 had the highest frequency with 326 instances. Four other response patterns had a frequency of greater than 10 instances including 1•8•3, 4•5•6, 4•8•6, and 7•5•3.

Figure 18 is a frequency distribution of three-key response patterns emitted more than once for GS-Sp98 during the acquisition session (top graph), the last session of FR-10 schedule maintenance (middle graph), and the first session of extinction (bottom

graph). During the acquisition, she emitted 11 different three-key response patterns with 1•5•3 being the most frequent with 226 instances. GS-Sp98 emitted 1•2•3 seventeen times, 4•5•6 sixteen times, and 7•8•9 sixteen times. During the last session of FR-10, she emitted 7 different three-key response patterns. 1•5•3 had the greatest frequency with 1282 instances. All other response patterns emitted during the last session of FR-10 ranged in frequency from 2 to 3 instances. GS-Sp98 emitted 17 different three-key response patterns with 1•5•3 being the most frequent with 754 instances during the first session of extinction. Six response patterns had a frequency of greater than 10 instances including 7•8•9 with 44 instances, 4•5•6 with 21 instances, and 1•2•3 with 17 instances.

CHAPTER 4

DISCUSSION

The results of this experiment closely resemble those reported by earlier investigators studying extinction with a variety of non-human species (e.g., Skinner, 1938; Ferster & Skinner, 1957; Keller & Schoenfeld, 1950) and with 2-year-old children (Weissberg & Fink, 1966) and adult mental patients diagnosed with schizophrenia (Hutchinson & Azrin, 1961).

The cumulative records generated by the subjects in this experiment (normal adults) are consistent with those reported previously for fixed ratio (FR) schedules of reinforcement with non-humans. In the beginning of extinction, all subjects responded at rates similar to the rate at which they responded during the previous FR schedule. Subsequently, their performances consisted of periods of rapid responding (“bursts” or “runs”) combined with increasingly long breaks in responding. The point at which each subject made the transition from normal responding to the “break and run” pattern was dependent on the FR value to which that subject was exposed prior to extinction. That is, lower schedule values resulted in earlier transitions to the “break and run” pattern during extinction. This phenomenon was well documented by Skinner (1938), Ferster and Skinner (1957) and Keller and Schoenfeld (1950).

Another similarity in results was the systematic decrease in behavior during extinction. The deceleration of behavior was related to the FR schedule value that the subject was exposed to prior to extinction. Higher schedule values resulted in slower

decelerations of responding per week. In other words, higher FR schedule values were more resistant to extinction (e.g., Skinner, 1938; Keller & Schoenfeld, 1957; Ferster & Skinner, 1957).

Besides the similarities in the moment to moment changes of behavior within the session and the change in behavior across days, changes in other temporal characteristics were also replicated. Subjects in the experiment who were exposed to schedule values higher than FR-1 displayed a bimodal distribution of interresponse times (IRT) during schedule maintenance. The bimodal distribution persisted early in the first session of extinction before becoming a variable, single modal distribution. AA-Sp98, who was exposed to an FR-1 schedule of reinforcement during maintenance, produced a single modal distribution of IRTs during schedule maintenance. During extinction, however, she produced a distribution with the same characteristics for a short period of time and then produced a variable single modal distribution much like the other subjects in the experiment. The point at which the distribution changed was dependent on the schedule of reinforcement: lower schedule values changing earlier than higher schedule values. These data are consistent with those reported by Blough (1963) in his work with pigeons and Millenson and Hurwitz (1961) with rats.

Similarly, all subjects in this experiment displayed a bimodal pattern of response durations during the maintenance phase of the experiment and the beginning of the first session of extinction. As the extinction session progressed, the distribution of response durations became single modal and dispersed. The point at which the distribution changed was dependent on the schedule of reinforcement to which the subject was exposed. Subjects exposed to lower schedule values displayed a change in the

distribution at an earlier point in extinction. These results are consistent with the results reported by Marguiles (1961) in his work with rats.

As in response duration, an analysis of the time between individual keystrokes (IKT) reveals a bimodal pattern for all subjects during the maintenance phase of the experiment and the early part of the first session of extinction. The point at which the IKT distribution was disrupted follows the pattern of other measures presented in this study and is dependent on the schedule under which the subject's behavior had been reinforced.

In addition to temporal variability of responding, there was topographical variability of old responses and the appearance of new topographies during extinction. During the maintenance phase of the experiment, all subjects pressed the 1•5•3 keystroke pattern with very little variation in the composition of the pattern or the length of the pattern. Like other measures reported in this study, this persisted for a period of time during extinction and then became disrupted. The point of disruption was dependent upon the schedule of reinforcement. Subjects exposed to lower schedule values showed topographical variability earlier in the session than subjects exposed to higher schedule values. These data are consistent with those presented by Eckerman and Lanson (1969) and Antonitis (1951).

Although extinction is a widely used procedure to decrease the frequency of behavior (e.g., Lerman, Iwata & Wallace, 1999), very little research has been published analyzing the effects of extinction on normal human subjects or the relationship between schedules of reinforcement and the effects of extinction. Nonetheless, the applied literature shows general agreement with respect to the effects of extinction on the overall

rate of responding and particular side effects of extinction such as topographical variability. Interestingly, Lerman, Iwata, and Wallace (1999) and Lerman and Iwata (1995) found a very low prevalence of extinction bursts. This finding may be due to their definition of an extinction burst as “an increase in responding during any of the first three treatment sessions above that observed during all of the last five baseline sessions or all of baseline if it was briefer than five sessions” (Lerman & Iwata, 1995, p. 93). The data presented in this experiment suggest that a moment-to-moment analysis of the effects of extinction may reveal information about these phenomena that is not apparent from a more macroscopic level (see also Vollmer, Iwata, Zarcone, Smith & Mazaleski, 1993).

Basic research on extinction effects on schedule performances of normal, adult humans is practically absent. This is perhaps due to the fact that researchers have not generally produced characteristic schedule control over these subjects’ performances (e.g., Weiner, 1969; Bentall, Lowe & Beasty, 1985; Bentall & Lowe, 1987). In this experiment, fixed ratio schedule performances closely resembled the performances of non-human species such as those reported by Ferster and Skinner (1957) and those reported by Flyger and Rosales-Ruiz (1997) and Rosales-Ruiz, Anderson, Hensley, and Koremura (1999) with normal human adults. However, Hayes and Ju (1998) assert that typical schedule performances by human subjects are insufficient to rule out the possibility of the performances being under the control of instructions. Sensitivity to changing contingencies or extinction is necessary to demonstrate that schedule performances are under the control of the programmed contingencies. Flyger and Rosales (1997) and Rosales-Ruiz, Anderson, Koremura and Hensley (1999) have shown sensitivity to changing schedule contingencies with FR and FI schedules. This

experiment extends those results to sensitivity to extinction. If the extinction performances are to be used as an indicator of sensitivity to schedules of reinforcement as Hayes and Ju suggest, then the current outcomes indicate that the behavior of the subjects in this experiment were clearly under control of the programmed contingencies. These data, as well as those reported by Flyger and Rosales-Ruiz (1997) and Rosales-Ruiz, Anderson, Koremura, and Hensley (1999) should restore confidence that schedule control and extinction can be replicated in the human operant laboratory. Perhaps these data will encourage a reexamination of the relative roles of rules or instructions and schedules of reinforcement in the human operant laboratory.

The failure of earlier investigators to produce characteristic performances under schedules of reinforcement has led to questions regarding the generality of behavioral processes seen with non-human species to human behavior and the value of this research to the study of human behavior (Baron, Perone, & Galizio, 1991). The implications of this conclusion are significant. If we cannot utilize the enormous volume of data generated in the operant laboratory with non-humans to guide our understanding of behavior with normal human beings, then we are left with a very tenuous basis for applied technology and the generality of basic principles derived from experiments with non-human animals is questionable. Baron, Perone, and Galizio (1991) identified procedural differences between human and non-human research as being one possible explanation for the researchers have has in replicating non-human studies in the operant lab with normal, adult humans. The method used in this study addresses this question by attempting to create an analog environment to the operant chamber used in the non-human literature. The results of this study along with those of Flyger and Rosales-Ruiz

(1997) and Rosales-Ruiz et. al. (1999) suggest that the behavioral principles documented so extensively in the animal literature generalize to normal, adult humans. The results of these studies suggest that schedules of reinforcement can be used as a baseline for studying phenomena such as rule governed behavior or verbal behavior.

The apparatus and methodology used in this study hold promise for studying basic behavioral processes in the human operant laboratory. The next logical step in this line of research is to examine the effects of extinction after exposure to other schedules arrangements such as fixed interval schedules and variable ratio and interval schedules. Additionally, the apparatus and methodology used in this study can be expanded to include discriminative stimuli, allowing multiple schedule arrangements, and possibly, the study of stimulus control along with schedules of reinforcement and extinction.

APPENDIX
ILLUSTRATIONS

Figure 1. Keyboard used as the operandum in this experiment. The black square delineates the numeric keypad.

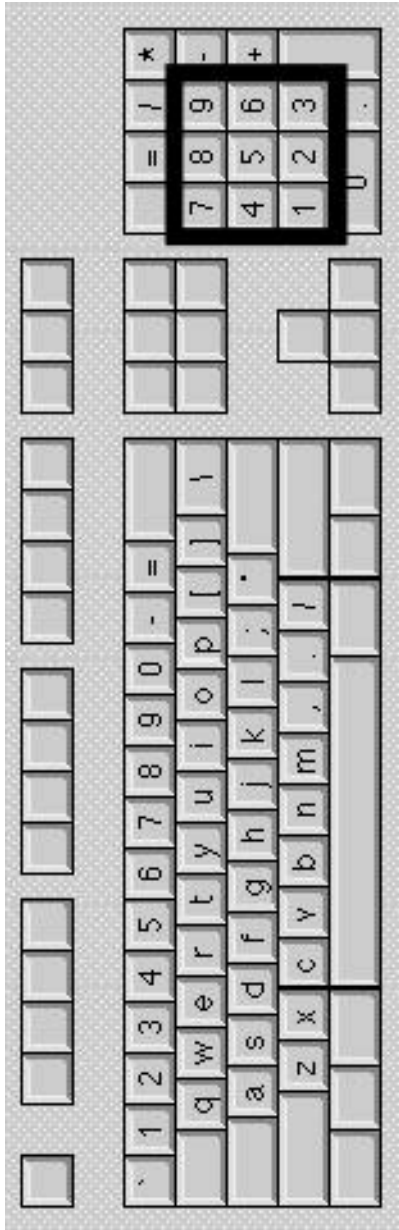


Figure 2. The subject was required to click the “start” button with the mouse before beginning the session.

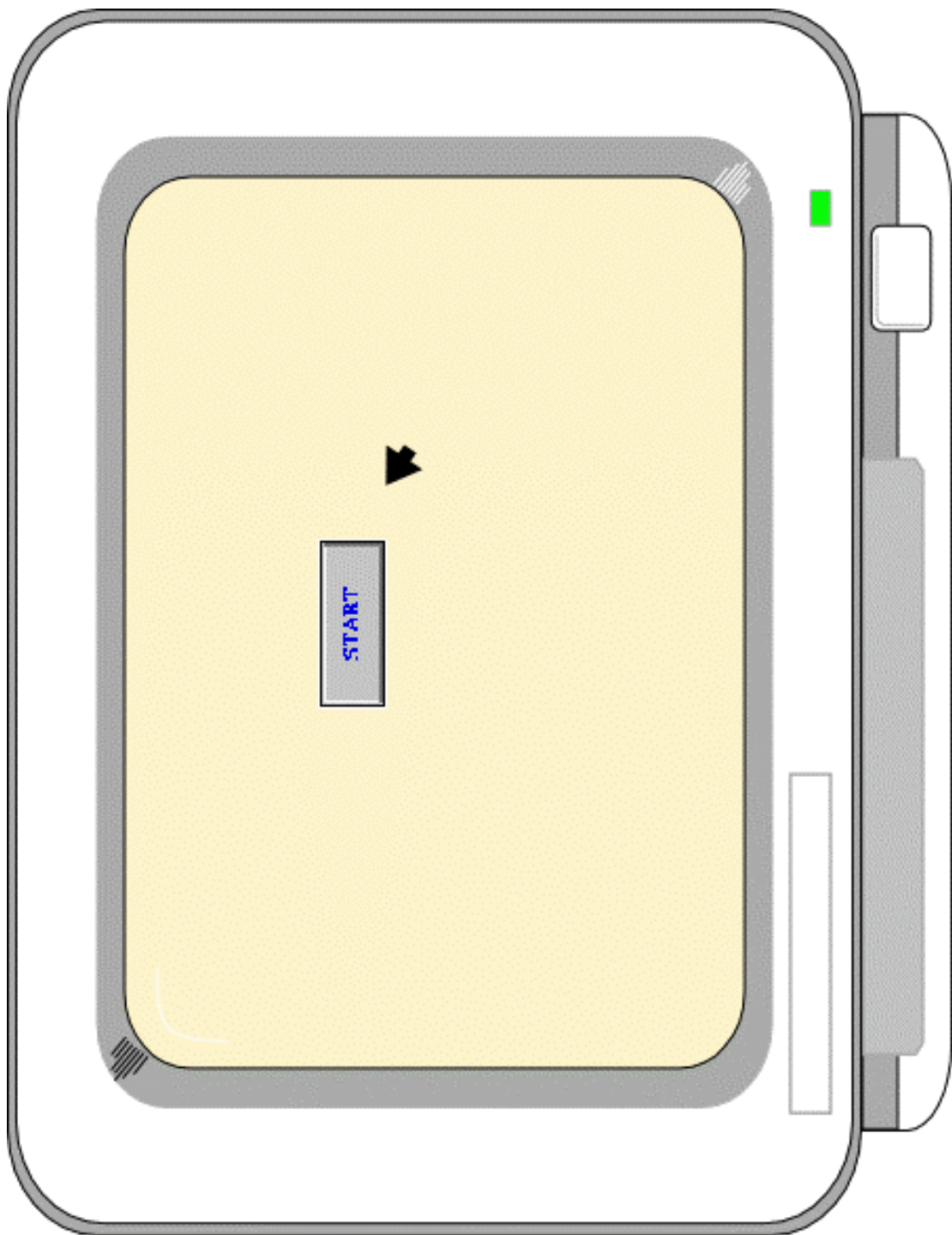


Figure 3. The subject saw a 3x3 grid on the computer monitor throughout the experiment. The squares on the grid corresponded with the keys 1-9 on the numeric keypad.

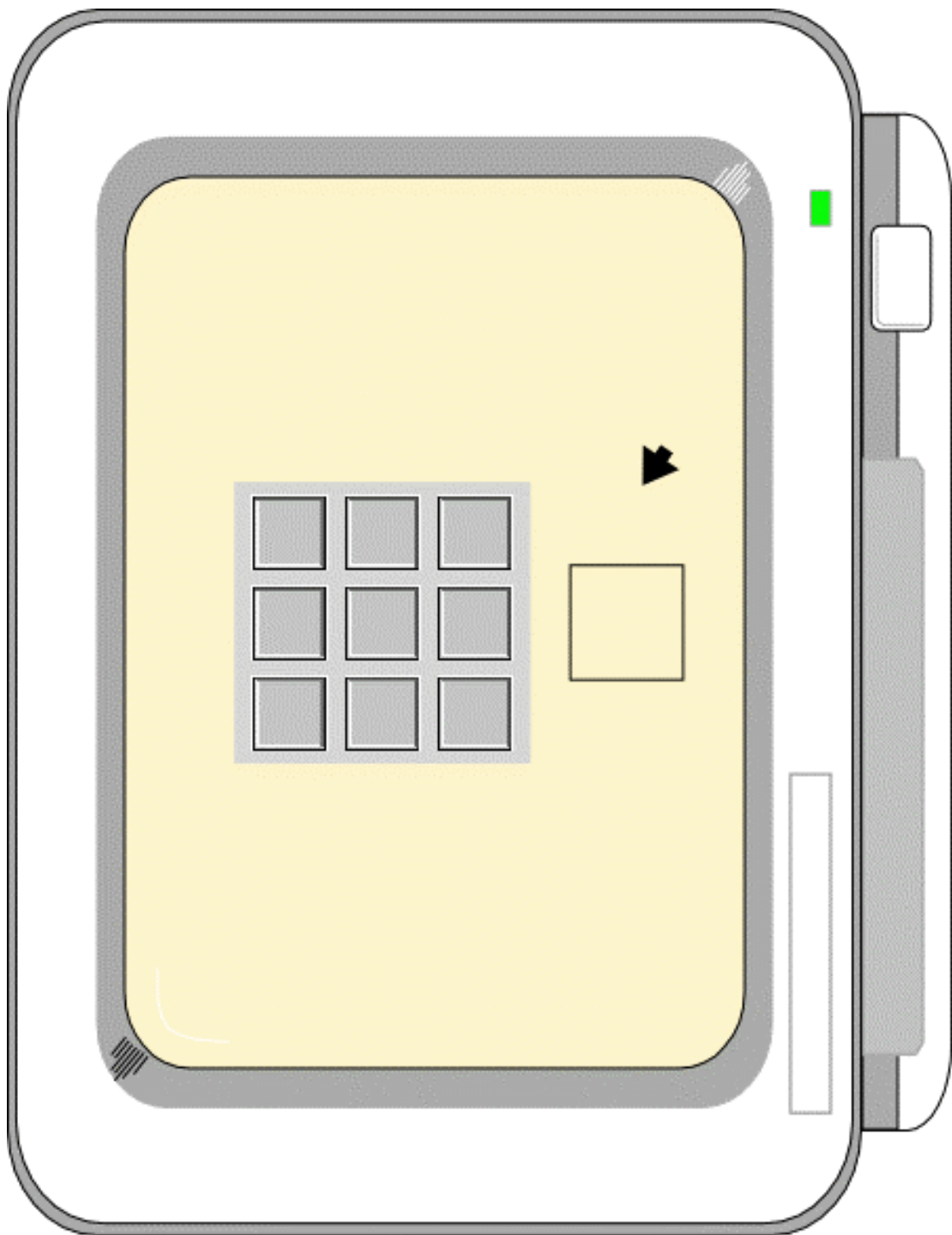


Figure 4. When the subject met the schedule contingency, a button with a speaker icon would appear below the grid.

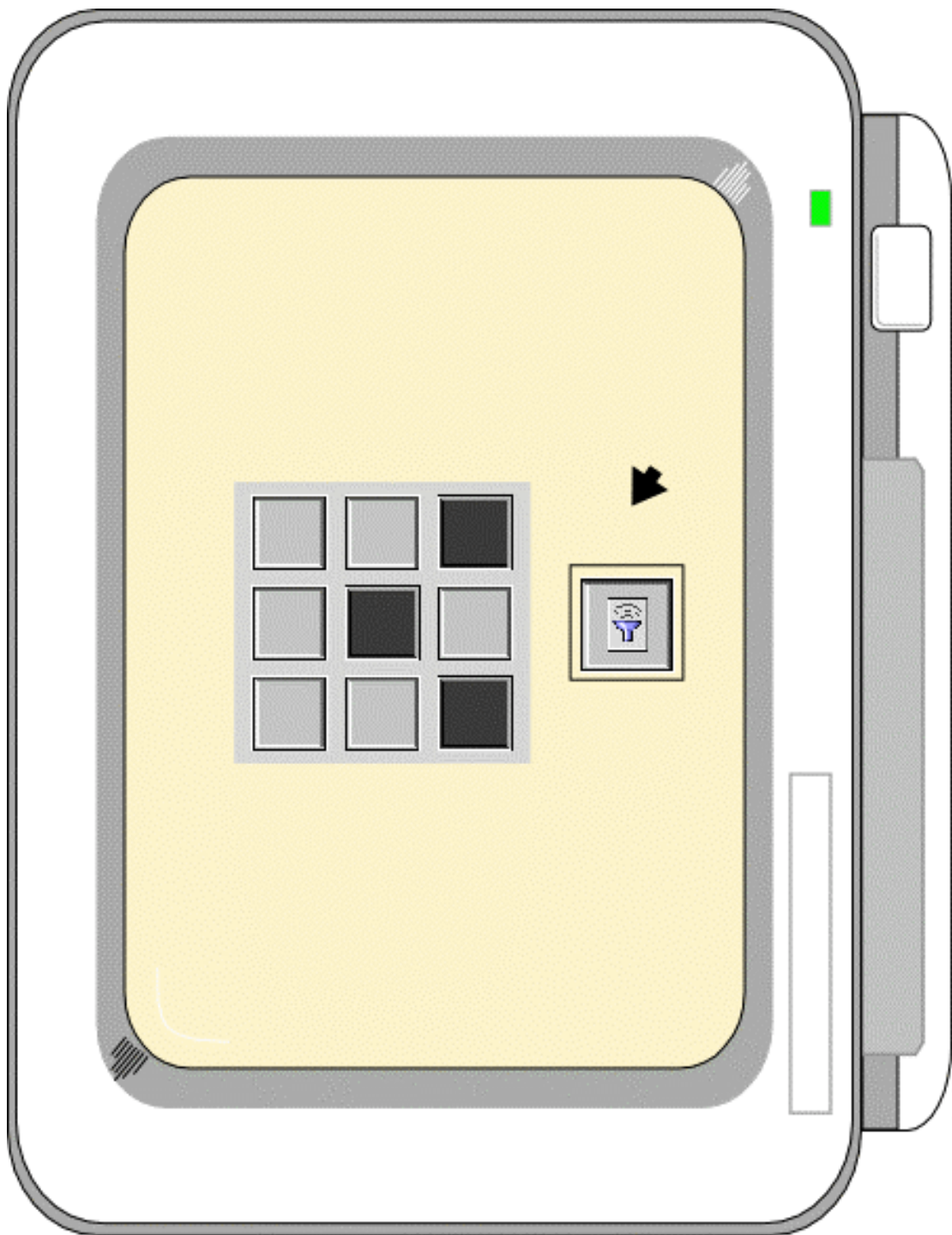


Figure 5. Changes in the grid as a result of the subject's key pressing behavior.

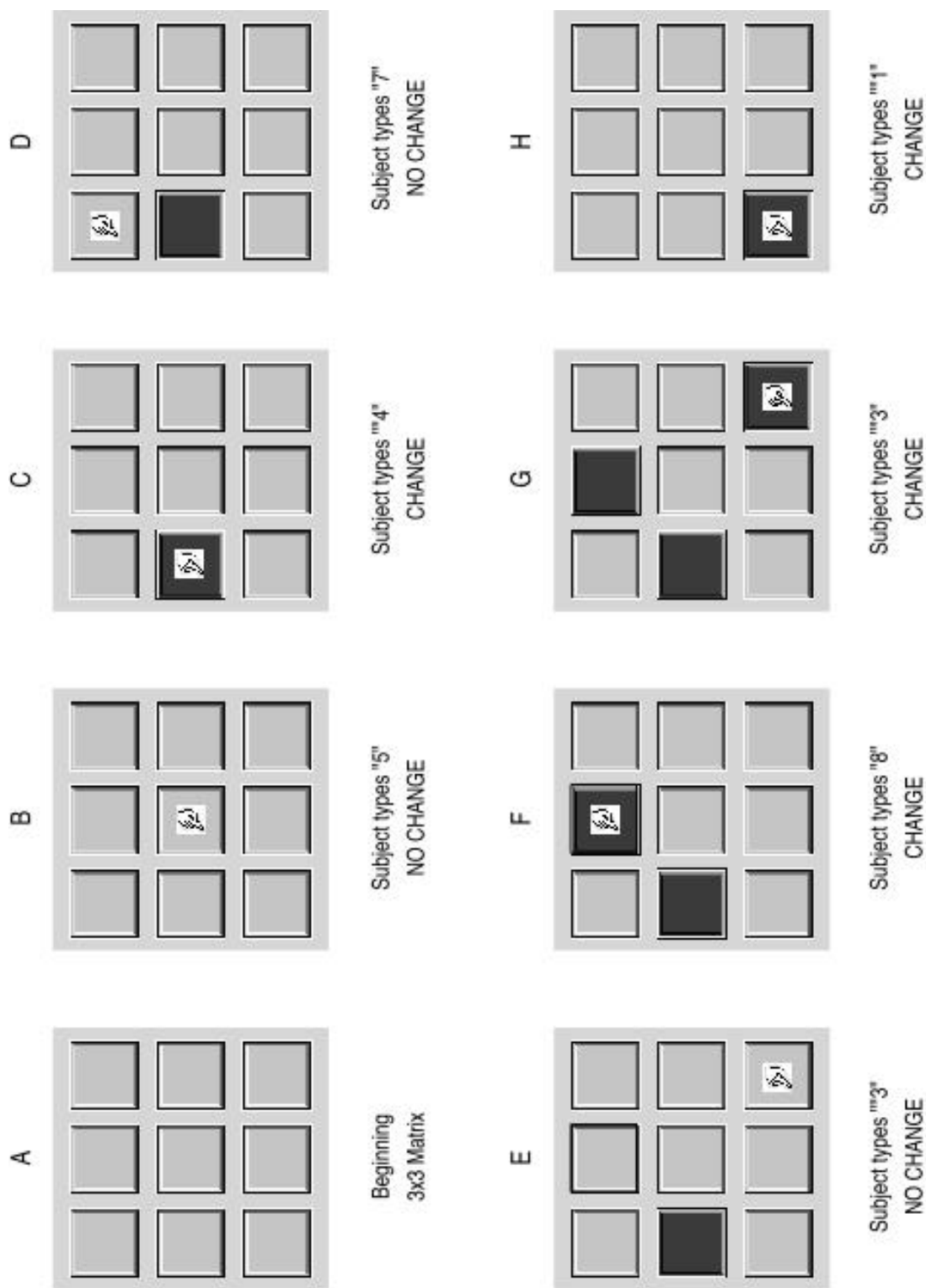


Figure 6. Changes in the grid from resulting from the subject's key pressing behavior (A) and the delivery of sound clip (B).

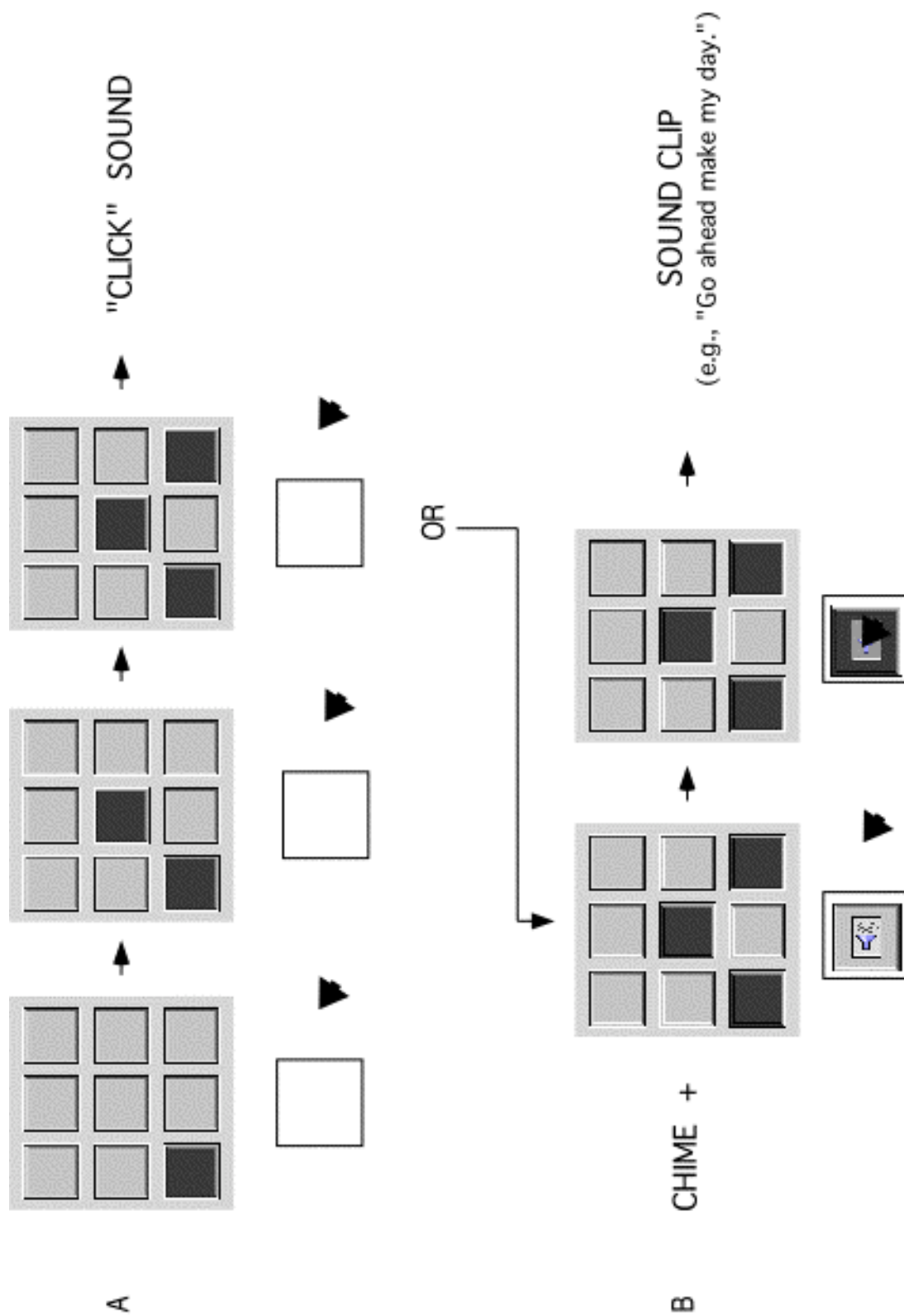


Figure 7. Daily celerations for subjects AA-Sp98 (FR-1), TW-Su98 (FR-5), and GS-Sp98 (FR-10).

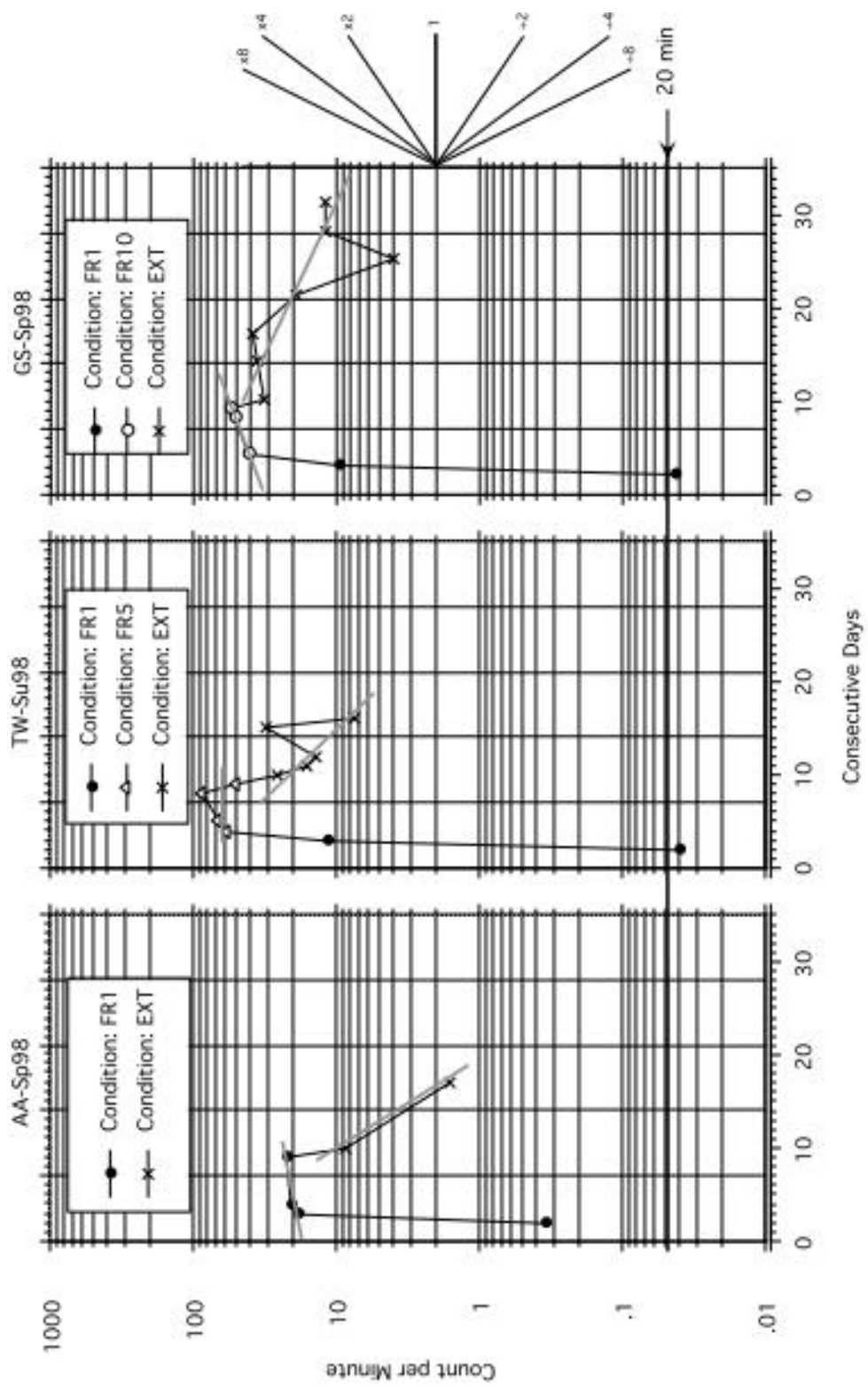


Figure 8. Cumulative records for AA-Sp98 during the last session of FR-1 (top) and the first session of extinction (bottom).

AA-Sp98

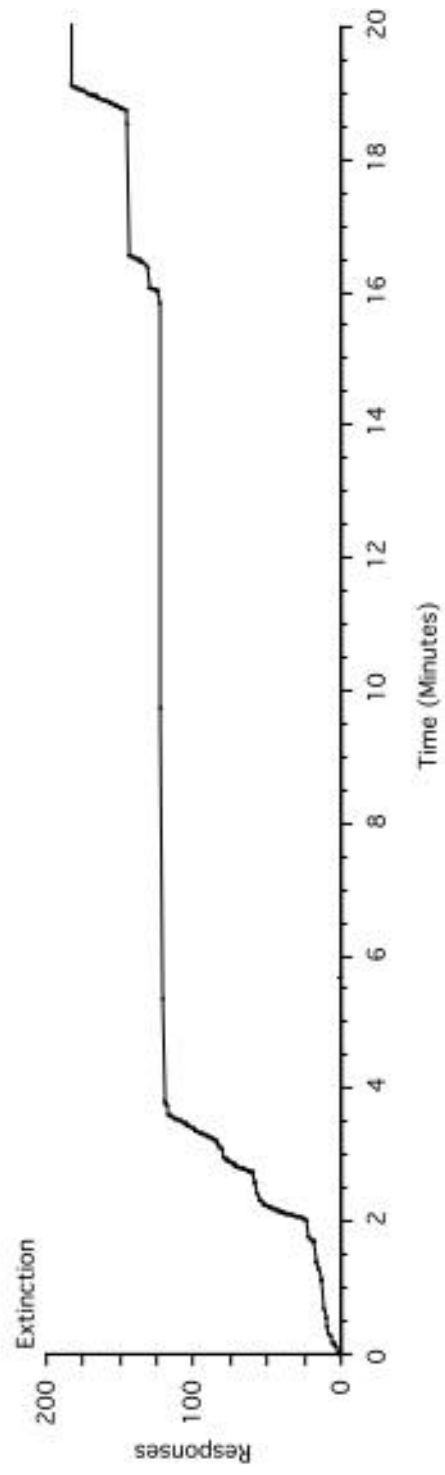
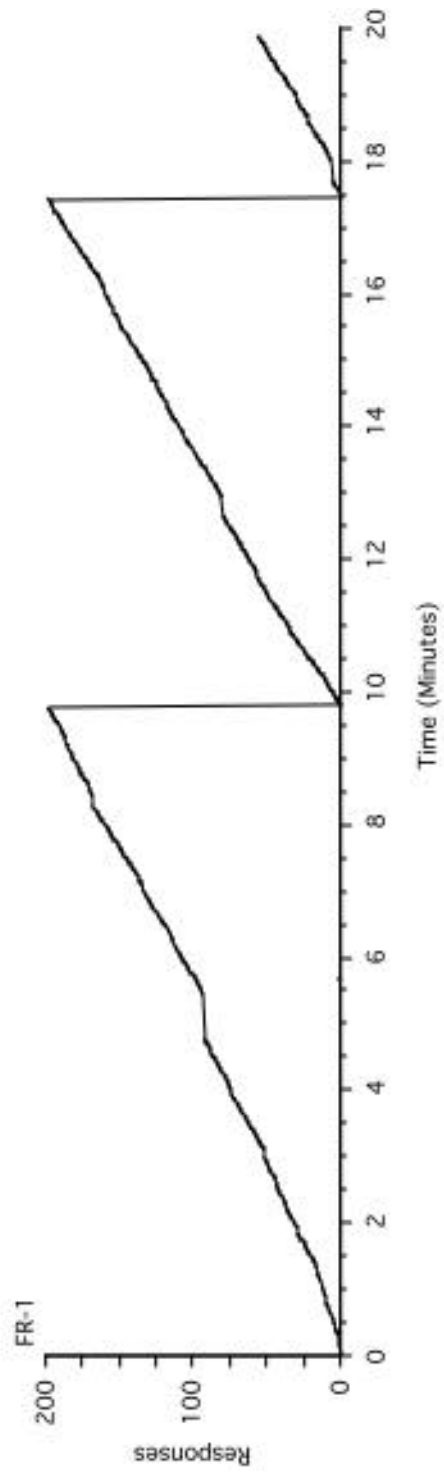


Figure 9. Cumulative records for TW-Su98 during the last session of FR-5 (top) and the first session of extinction (bottom).

TW-Su98

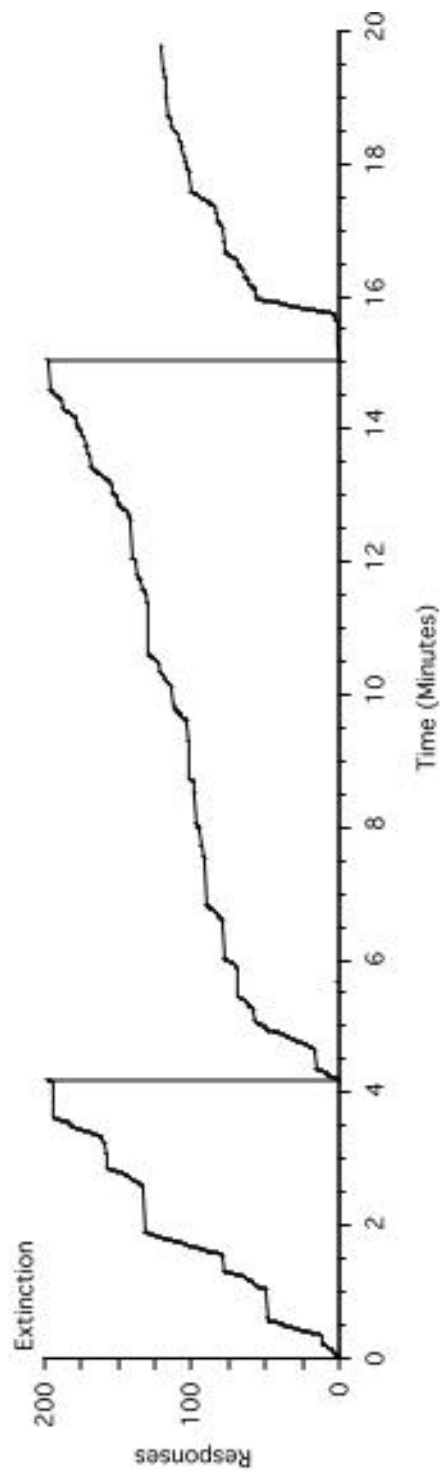
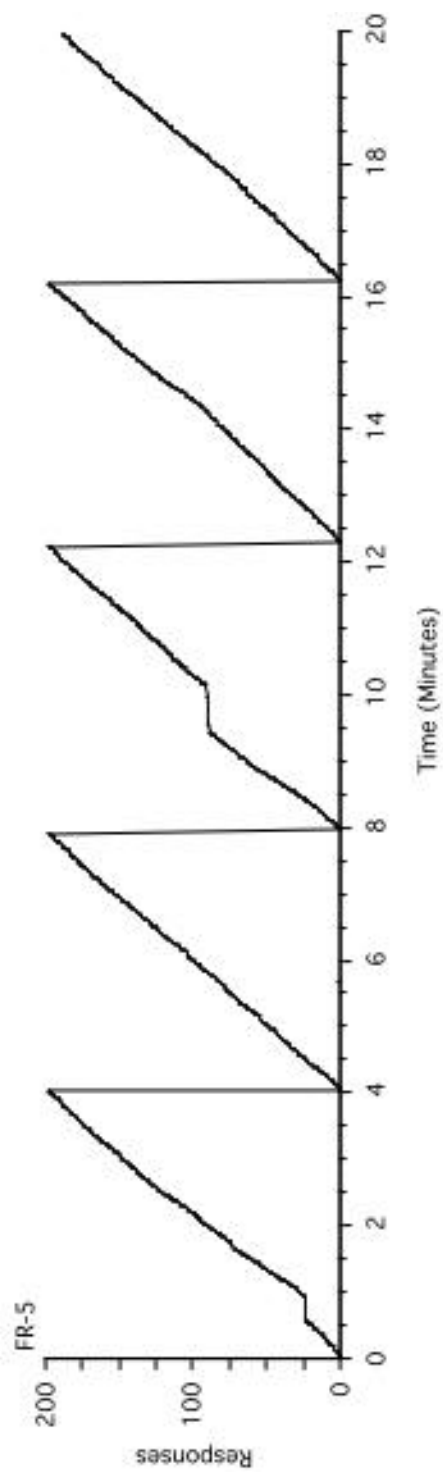


Figure 10. Cumulative records for GS-Sp98 during the last session of FR-10 (top) and the first session of extinction (bottom).

GS-Sp98

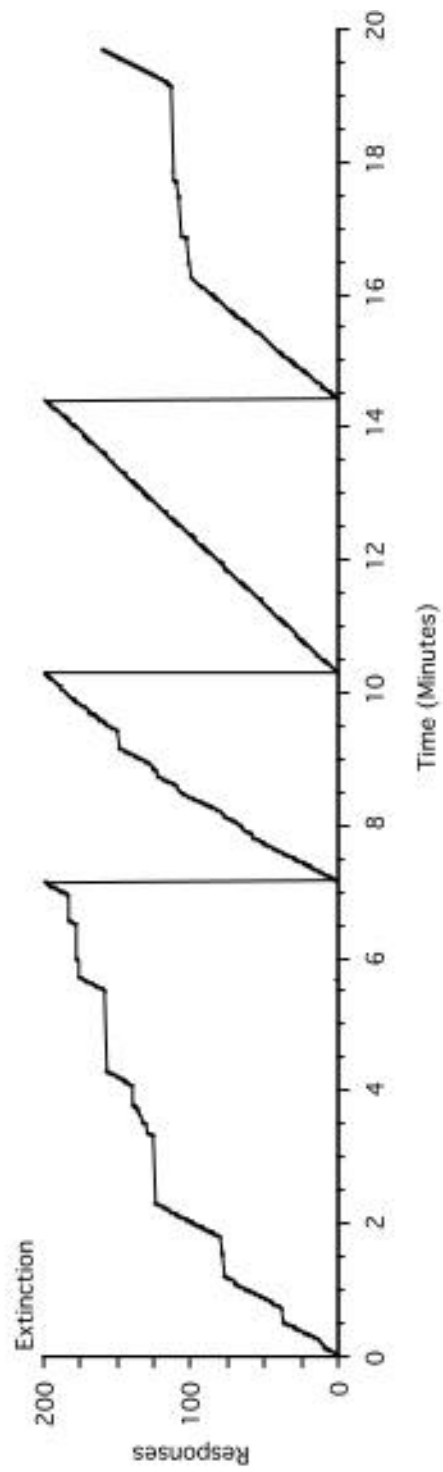
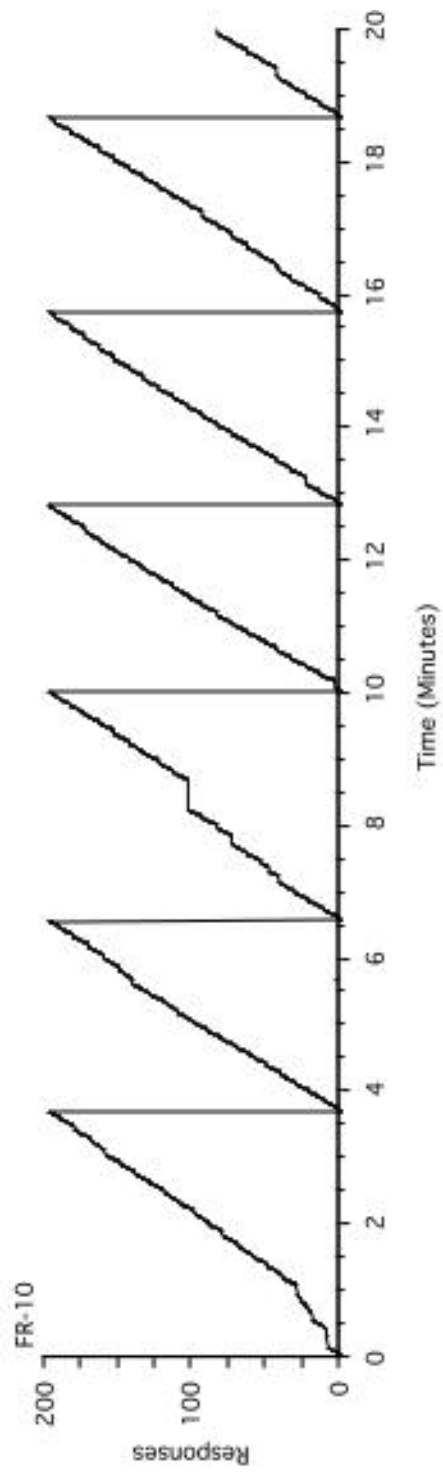


Figure 11. Response durations in seconds over time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98 (top), TW-Su98 (center), and GS-Sp98 (bottom).

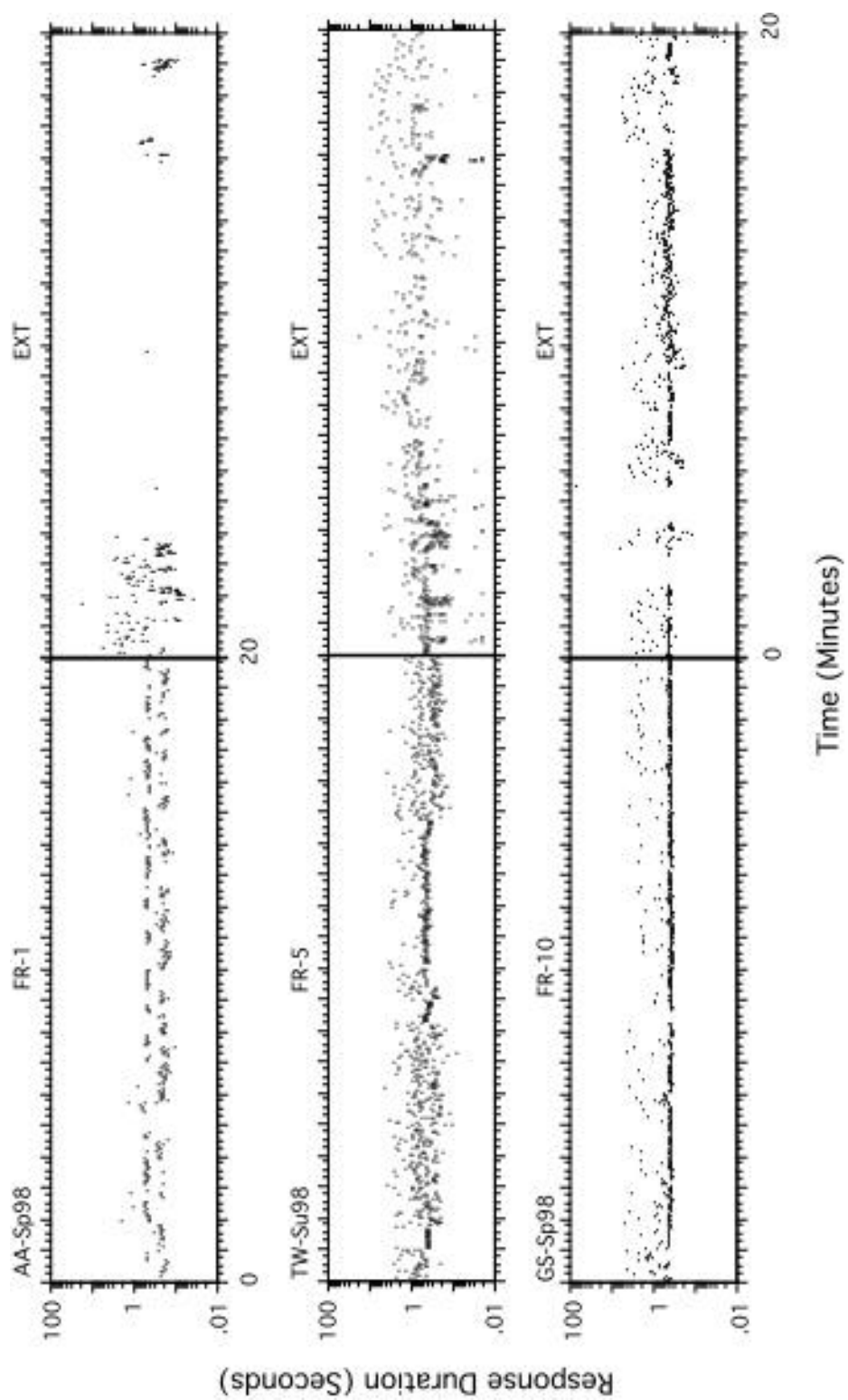


Figure 12. Interresponse times (IRT) in seconds over time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98 (top), TW-Su98 (center), and GS-Sp98 (bottom).

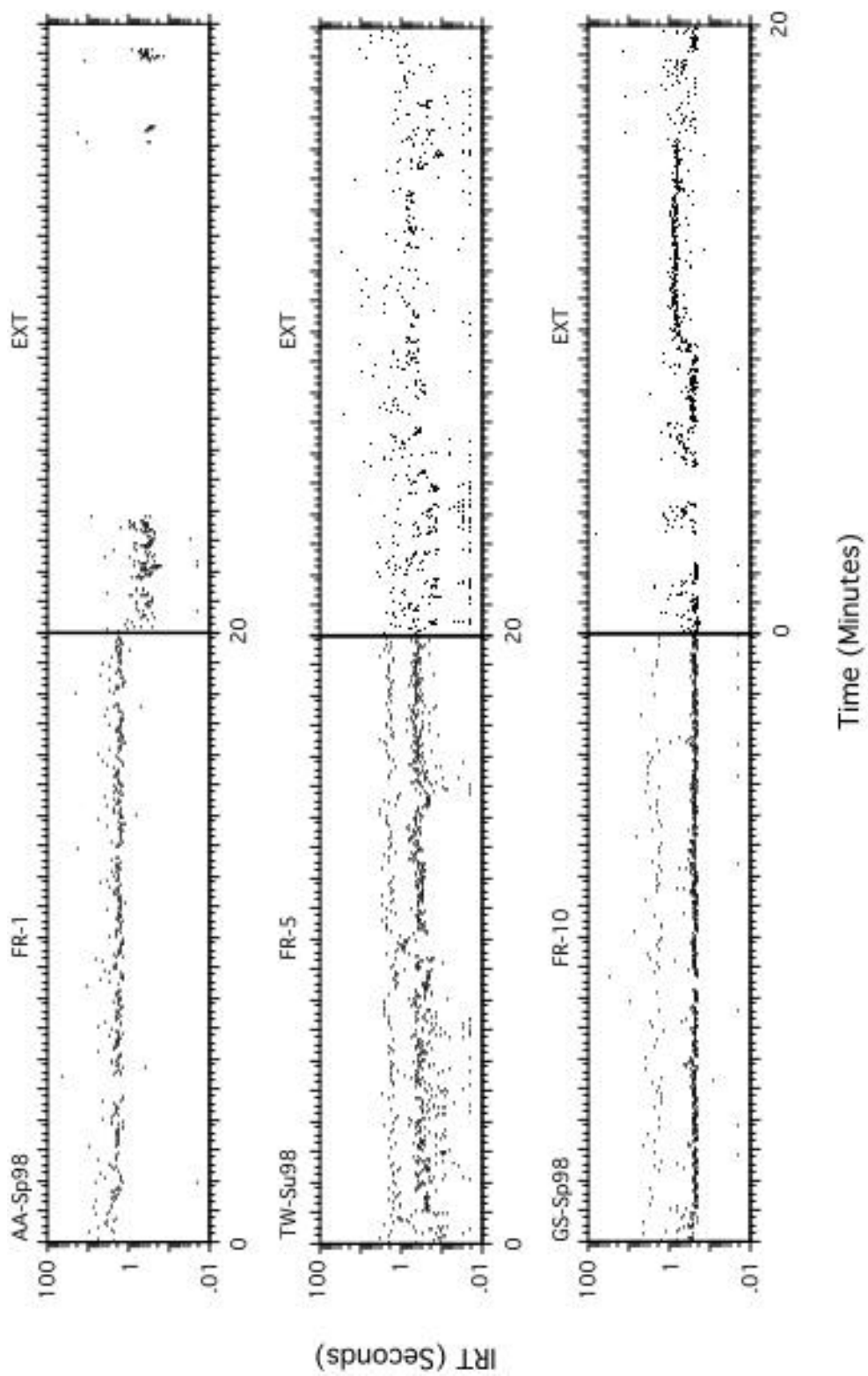


Figure 13. Interkeystroke times (IKT) in seconds over time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98 (top), TW-Su98 (center), and GS-Sp98 (bottom).

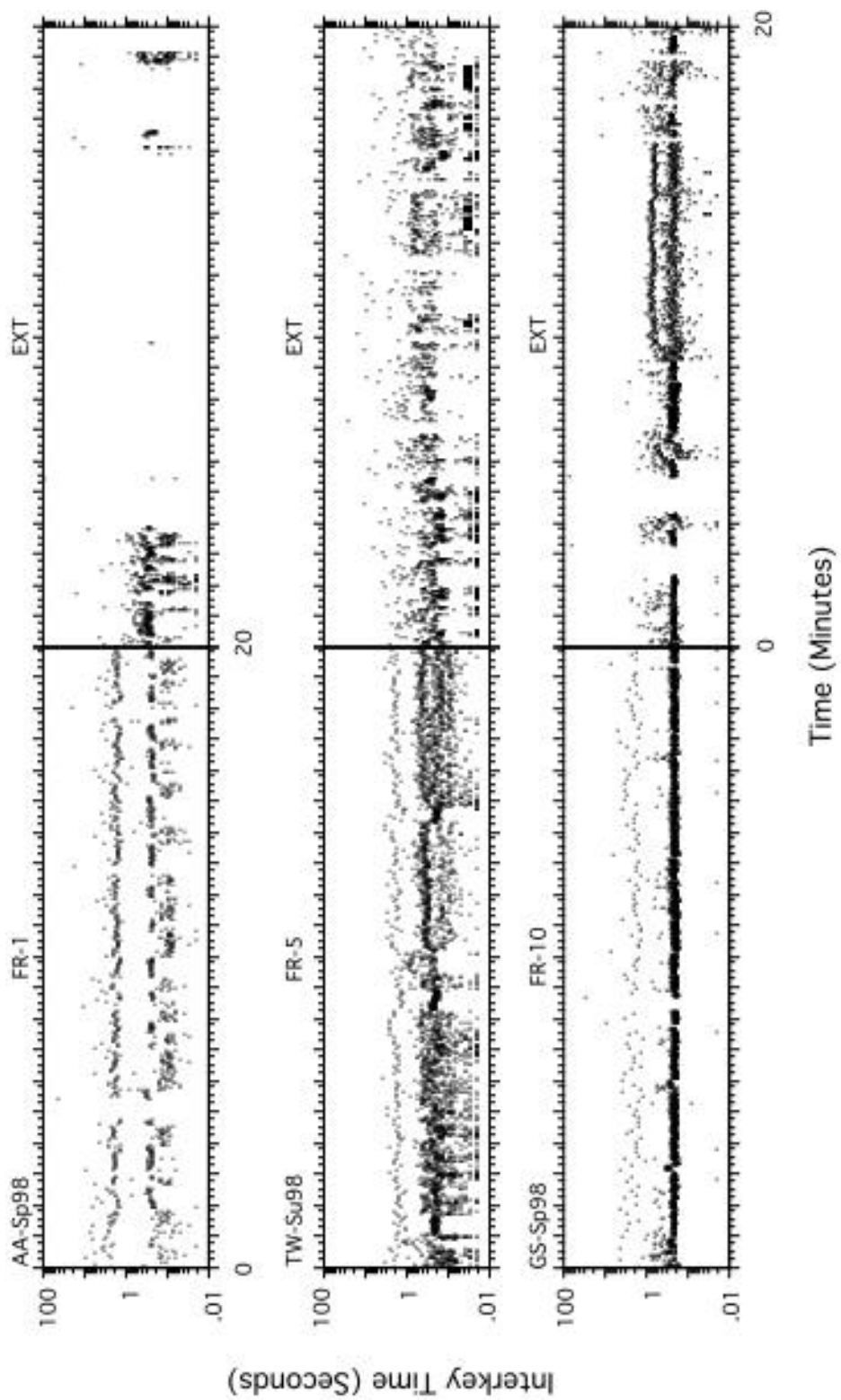


Figure 14. Keystrokes as they over time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98 (top), TW-Su98 (center), and GS-Sp98 (bottom).

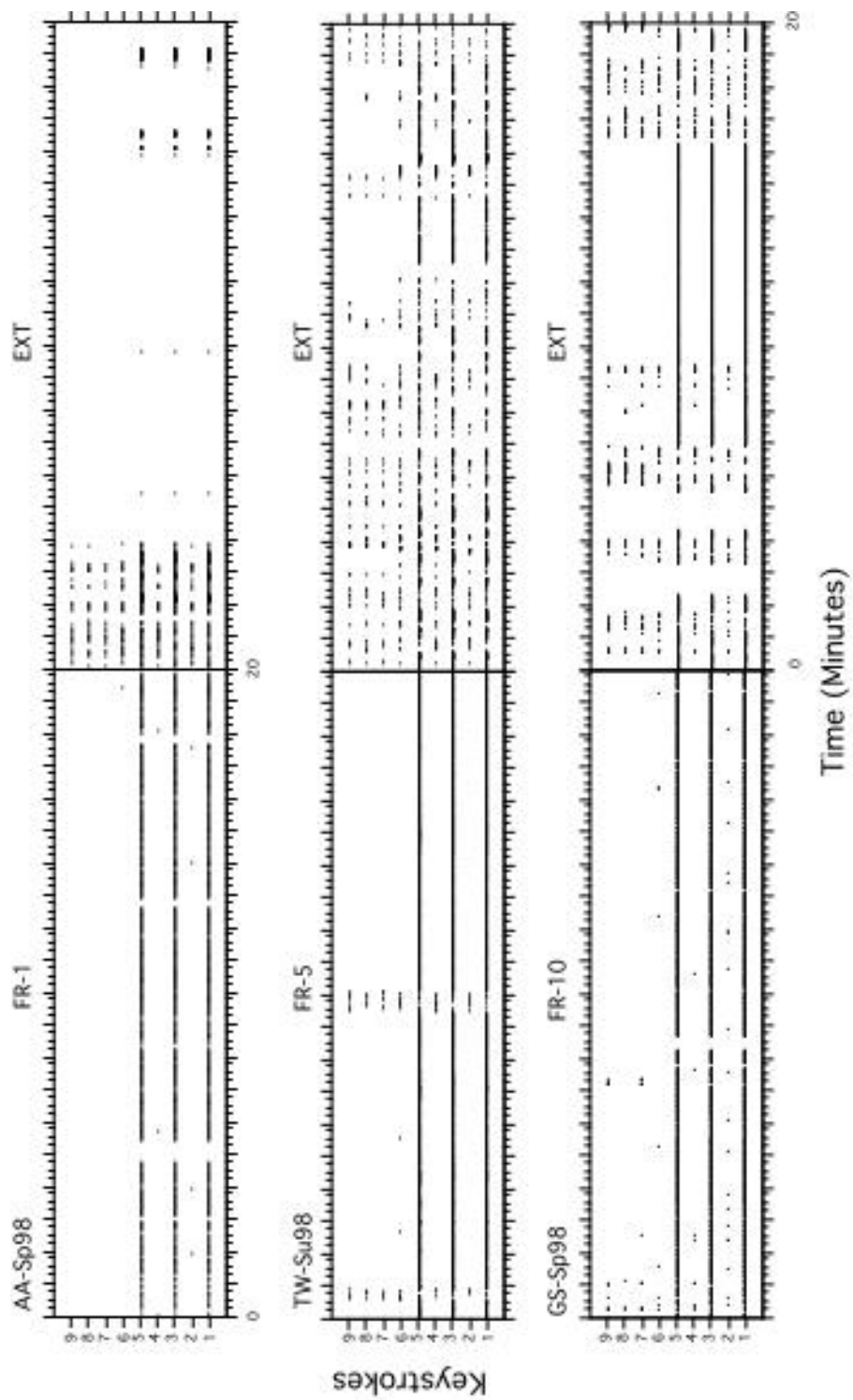


Figure 15. Pattern length in keystrokes over time during the last session of schedule maintenance and the first session of extinction for subjects AA-Sp98 (top), TW-Su98 (center), and GS-Sp98 (bottom).

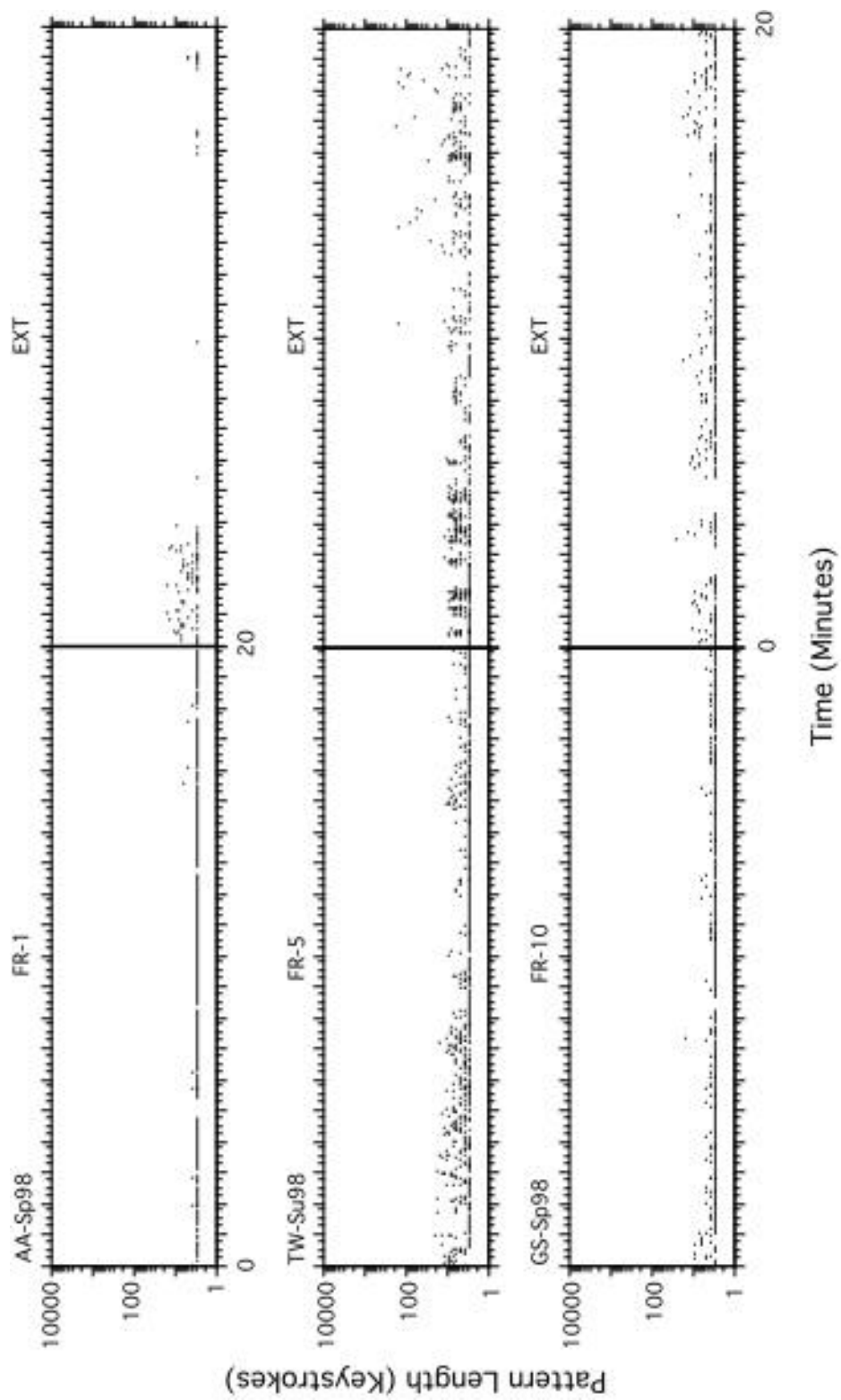


Figure 16. Frequency of three key response patterns during acquisition, schedule maintenance, and extinction for subject AA-Sp98.

AA-Sp98

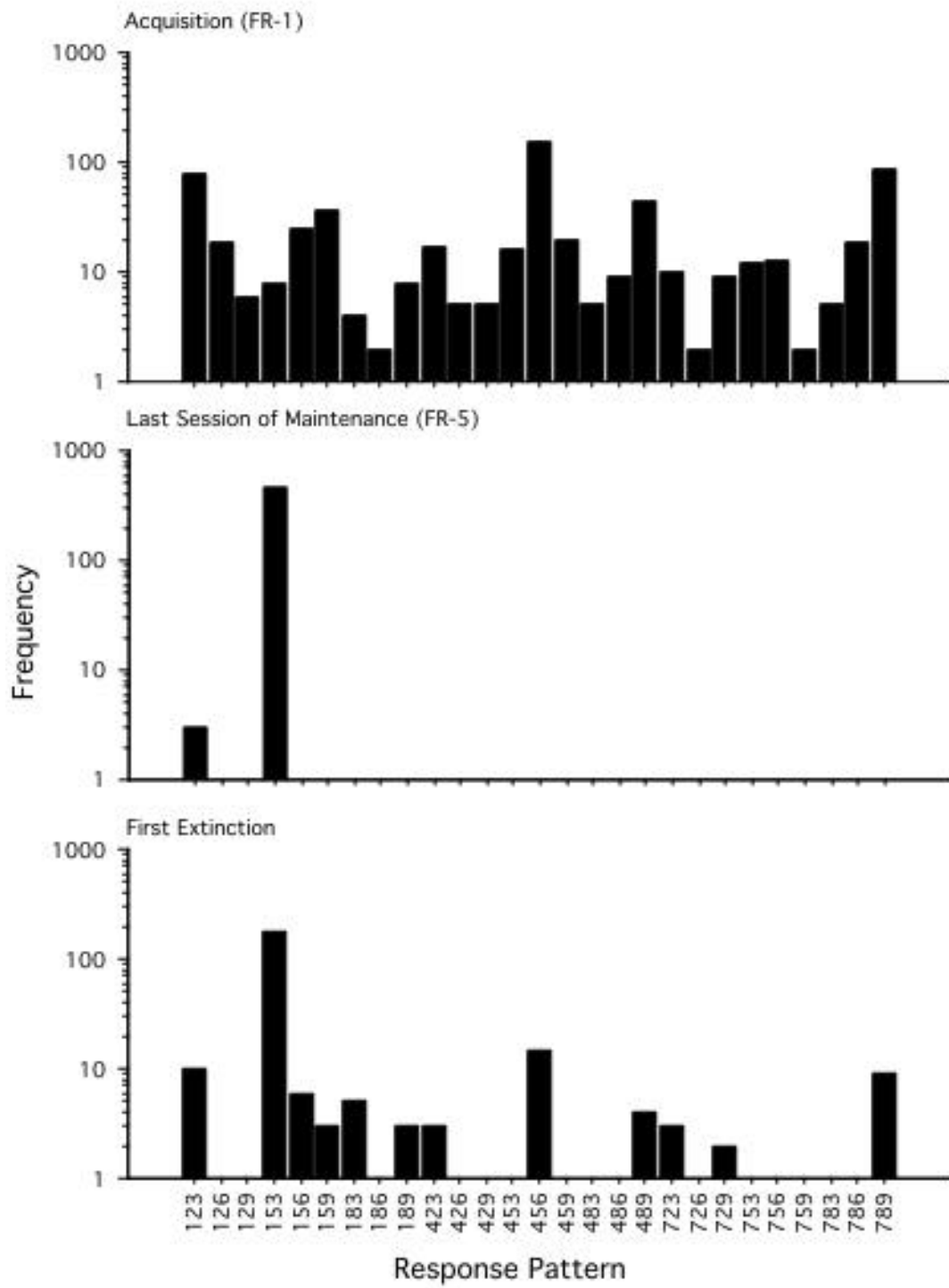


Figure 17. Frequency of three key response patterns during acquisition, schedule maintenance, and extinction for subject TW-Su98.

TW-Su98

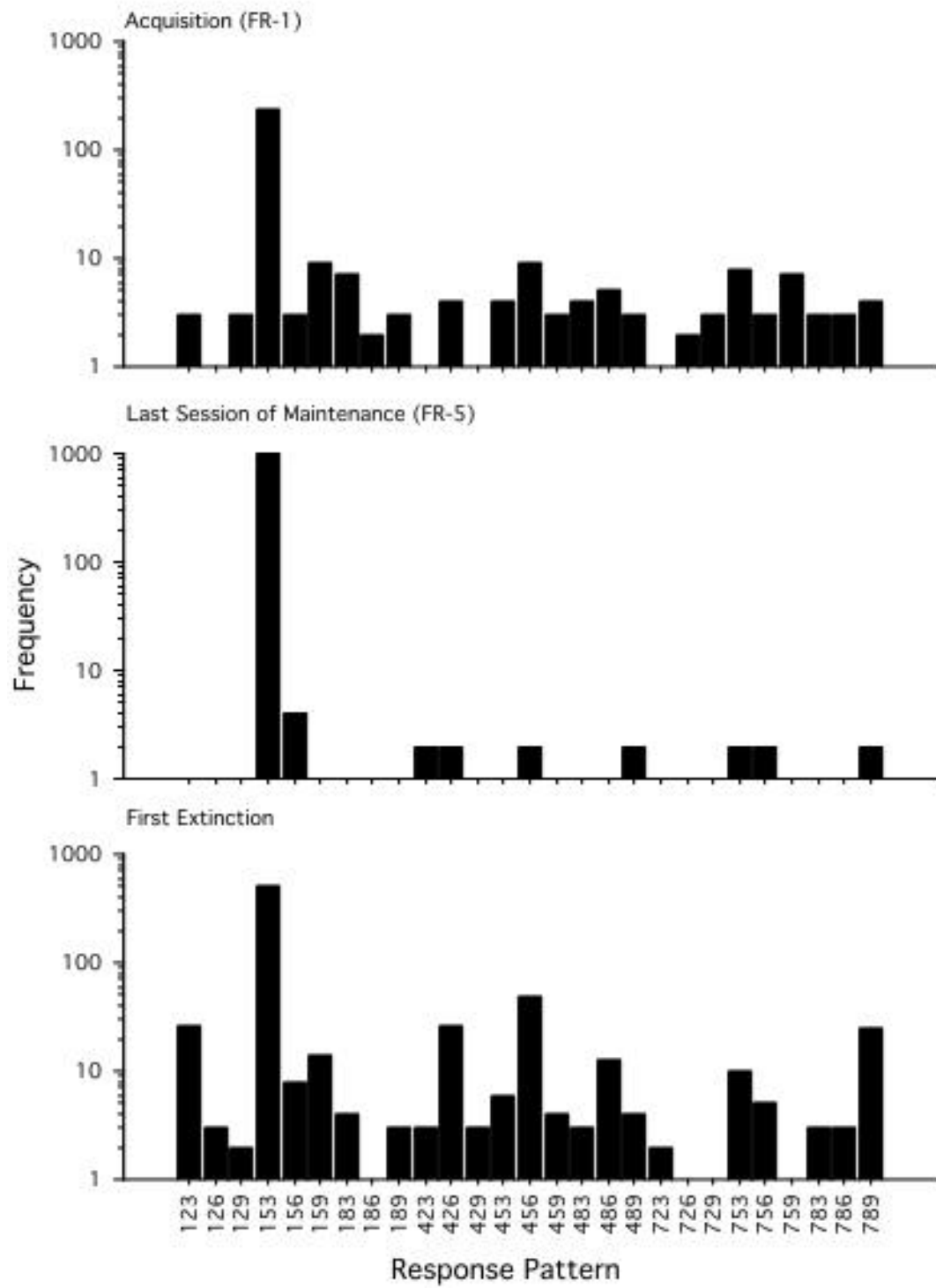
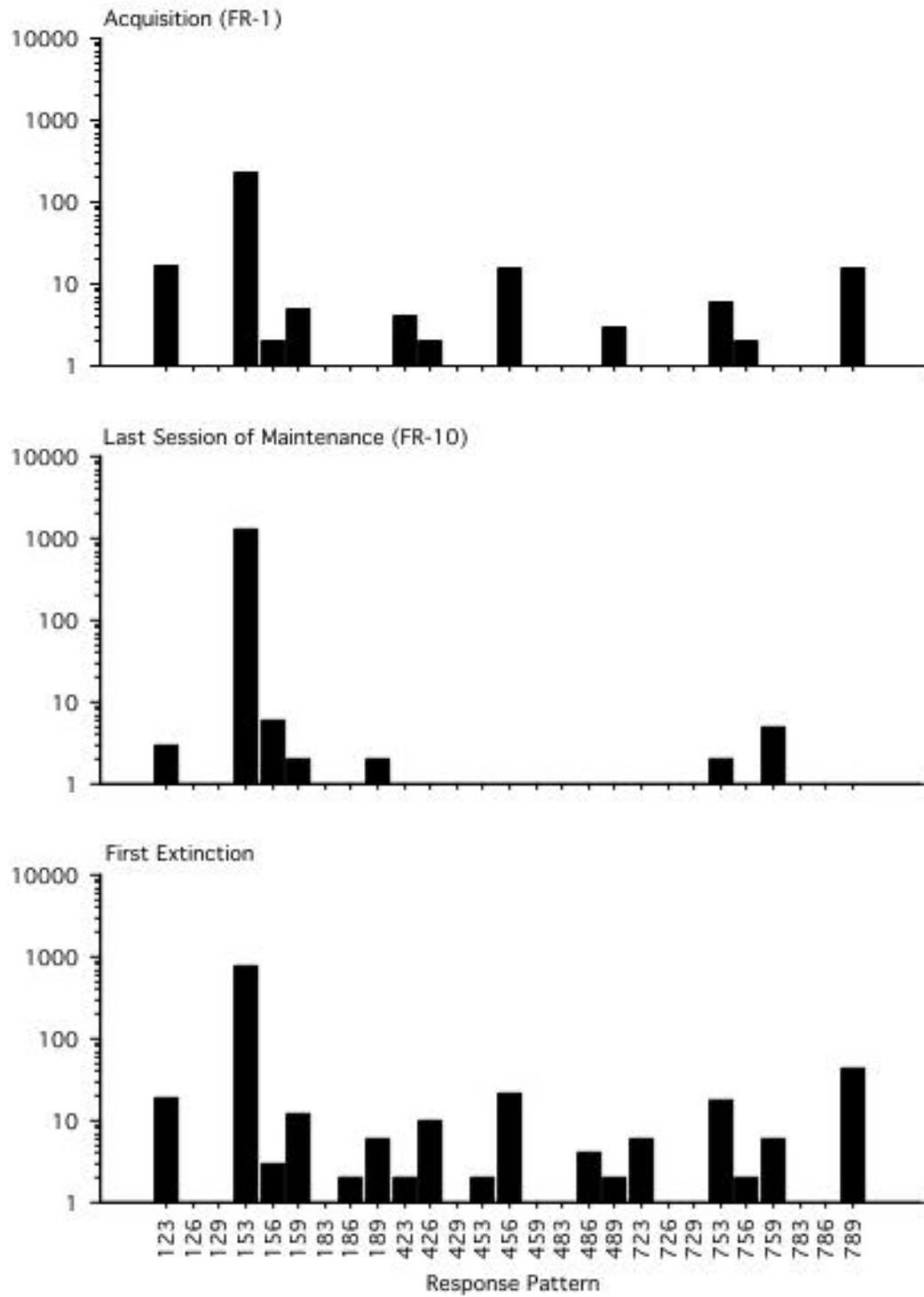


Figure 18. Frequency of three key response patterns during acquisition, schedule maintenance, and extinction for subject GS-Sp98.

GS-Sp98



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